ATMOSPHERIC ANALYSIS CAPABILITY TO SUPPORT ELECTROMAGNETIC APPLICATIONS

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Introduction

As **tactical applications and users** have become more sophisticated, a need for a consistent four dimensional volume of environmental information has become evident. This paper discusses the Naval Research Laboratory's first effort to provide a three dimensional consistent volume of atmospheric data to support an electromagnetic propagation application, the Radio Physics Optics (RPO) model. From this experience, and as computer workstations become more powerful the Laboratory hopes to be able to forecast as well as analyze the atmospheric volume adding the fourth dimension, time. This work was funded by the Office of Naval Research and the Oceanographer of the Navy through the Space and Naval Warfare Systems Command.

The Ship Anti-submarine warfare Readiness Effectiveness Measurement (SHAREM) 110A exercise in the Arabian Gulf was chosen as the first opportunity to test such an analysis scheme in an operational setting. SHAREM exercises are coordinated by the Surface Warfare Development Group (SWDG) in Little Creek, Virginia. They are Naval Exercises that have a scientific bent to them allowing for the investigation of a particular phenomenon.

One of the areas that SHAREM 110A was designed to examine was the radar ducting environment of the Arabian Gulf. The participating vessels were an Aegis Cruiser USS Lake Erie, a destroyer USS David R Ray, a frigate USS Vandegift and a research vessel from the Naval Oceanographic Office USNS Silas Bent. To provide observation data for the analysis, the USNS Silas Bent, USS David R Ray, and USS Lake Erie all had a balloon sounding capability. A rocketsonde was also installed aboard USS Lake Erie and a helicopter with a dropsonde capability was embarked aboard USS Vandegrift. Special surface meteorological sensing instruments were installed aboard USS Lake Erie. Five fights by an instrumented C-130 provided by the Met Research Flight of the UK provided data which will be used to verify the analysis.

Operational Concept of SHAREM 110A

Figure 1 shows the communications links which were utilized during the exercise. The data flow starts with the running of a regional forecast model at the Fleet Numerical Meteorology and Oceanography Center (FNMOC). This model, the Naval Operational Regional Atmospheric Prediction System (NORAPS) is a 36 level model that was run at a 20 km horizontal resolution. Meteorologists are accustomed to using model data which has been interpolated on constant pressure levels such as the 500 mb surface. In this case as much vertical structure as possible was required. The model data was provided to the site in Bahrain (Naval Pacific Meteorology and Oceanography Detachment, NPMOD, colocated with the U S Naval Central Command, NAVCENT) in Sigma-P coordinates. Sigma-P is the ratio of the grid pressure to the surface pressure. The lower 18 levels (up to approximately 10,000ft) of wind (U and V components), temperature, and mixing ratio and the terrain pressure and surface temperature were sent to NPMOD. This model data was provided at forecast intervals of 3 hours from 9 hours past the model analysis time (OZ or 12Z) out to 24 hours.

The observations from the participating ships were sent back to NPMOD on a circuit known as the Officer in Tactical Command Information Exchange System (OTCIXS). This is a satellite communications link for ships operating together. The World Meteorological Organization (WMO) codes were used to encode the observations using the standard definitions of significant data points (Federal Meteorological Handbook No 4). The analyses were later redone in Monterey using radiosonde, dropsonde, and rocketsonde data which were reprocessed from data taken every 2 seconds in an attempt to capture more detail than required by the standard definition (except for the USS David R Ray's soundings where only the encoded message was available).

At NPMOD the model data was fuzed with the observation data (both land and ship observations) using the analysis techniques to be discussed in the next section and 3-D volumes of modified refractivity index (M-Units) were calculated. A small subset of M-Units plus the parameters used to calculate the evaporative duct height were packaged for transfer to USS Lake Erie via OTCIXS for use with RPO,

Techniques utilized for data fusion at NPMOD

The Multivariate Optimum Interpolation (MVOI)(Barker 1992) is the central component of the data fusion process. The MVOI is the analysis scheme used at FNMOC to analyze the atmosphere in preparation for forecast model initialization. As implemented at FNMOC, MVOI is a geostrophically constrained analysis of heights and winds on standard meteorological pressure surfaces (1000 - 10 rob). The application has controls for not using the geostrophic constraint during the analysis. The MVOI is capable of analyzing a wide array of different atmospheric observation types including standard surface observations, radiosonde observations, aircraft observations, Special Sensor Microwave Imagery (S SMI), satellite soundings, and cloud track winds.

During SHAREM 110A the goal was to support the RPO application with vertical profiles of refractivity derived from moisture and temperature along with the surface wind speed. These profiles would need to capture as accurately as possible the vertical atmospheric structures. In order to attempt to capture the vertical features desired, the sigma-P definitions from the supporting NORAPS model were used. The lowest 18 **sigma-P ratios were multiplied by a surface pressure from one** of the participating units to define 18 analysis levels between the surface and approximately 10,000 ft. Table 1 shows the sigma-P ratios used, To provide data for each analysis level the profile data (radiosondes, dropsondes, and rocketsondes) were interpolated to the level using log- P as the vertical coordinate.

0.999	**0.969**	**0.91**
0.9965	**0.96**	**0.895**
0.993	**0.95**	**0.87**
0.989	**0.94**	**0.83**
0.984	**0.93**	**0.77**
0.977	**0.92**	**0.6925**

Table 1: Sigma-P Ratios used during SHAREM **110A**

Since MVOI does not provide any information about the moisture distribution, a Cressman dewpoint depression analysis was provided by Dr James Goerss of NRL. The Cressman analysis only uses radiosonde data in the analysis. The Cressman analysis is performed in three passes with the initial radius of influence set to eight grid points.

During the exercise the temperatures were computed from the layer thicknesses. Figure 2 shows one of the resulting analyzed profiles. The noise in the profile was recognized as temperature buckling (Barker 1980). This is caused by small errors in the height analysis which result in large temperature deviations for thin layers. To correct the temperature buckling problem a Cressman temperature analysis was also implemented. The heights from the MVOI and the temperatures from the Cressman analysis were then placed into hydrostatic balance (Barker 1980). Figures 3 through 6 show results after these changes.

Figure 3 is the temperature and moisture profiles from a single sounding from the USS Lake Erie. The figure shows that the analysis forced the profile closer to the observed profile demonstrating some ability to reflect some of the structure in the sounding. However, the higher in the volume the smoother the analyzed profile becomes due to the reduced density of analysis levels.

Figures 4 through 6 are from a time when three simultaneous soundings were taken. Here a low level inversion is analyzed based on the feature from the USNS Silas Bent sounding. In this case the USS Lake Erie is on the northwest side of the other ships. The USNS Silas Bent is about one grid point south and USS David R Ray is about one grid point to the east.

In digitized (gridded) atmospheric data it is generally understood that the value at the grid point represents the average value of that parameter in the volume surrounding that grid point. The Cressman analysis techniques not only averages within the grid volume but allows data from, in this case, 8 grids points away to have an effect on the value at a specific grid point. Here the interplay of the 3 radiosondes has produced a shallow inversion over the three depicted locations. The soundings would seem to show that the inversion only existed at the location of the USS Silas Bent. Atmospheric features that are smaller than the horizontal spacing of the grid will be miss represented as in this example.

summary

The analysis software developed to support the SHAREM exercises has shown skill in improving forecast fields of temperature and moisture by using real time observations. This improvement includes modifying the values of the points closer to those observed and more accurately depicting the vertical structure. These volumes of data will next be checked against an independent data set provided by the Met Research Flight instrumented C-130 to quantify the accuracy.

References

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Barker, E. H. 1992: Design of the Navy's Multivariate Optimum Interpolation Analysis System. Weather and Forecasting, Vol 7 No 2220-231

Federal Meteorological Handbook No 4, Radiosonde Code (Standards and Procedure for the Coding of Radiosonde Reports), Revised January 1,1976, Second Edition, U S Department of Commerce, U S Department of Defense, U S Department of Transportation

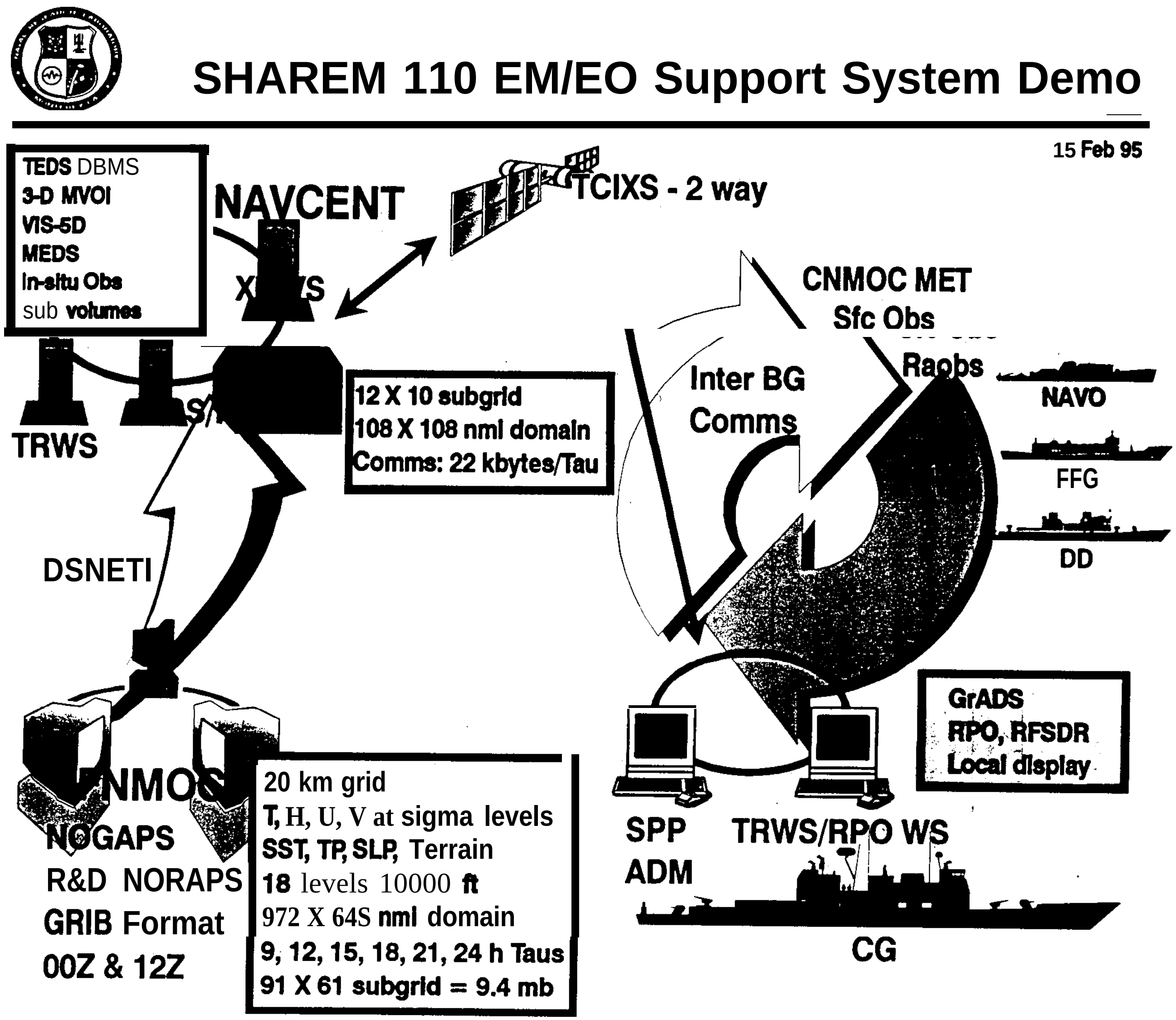


Figure 1: Data Transfers During SHAREM 110A

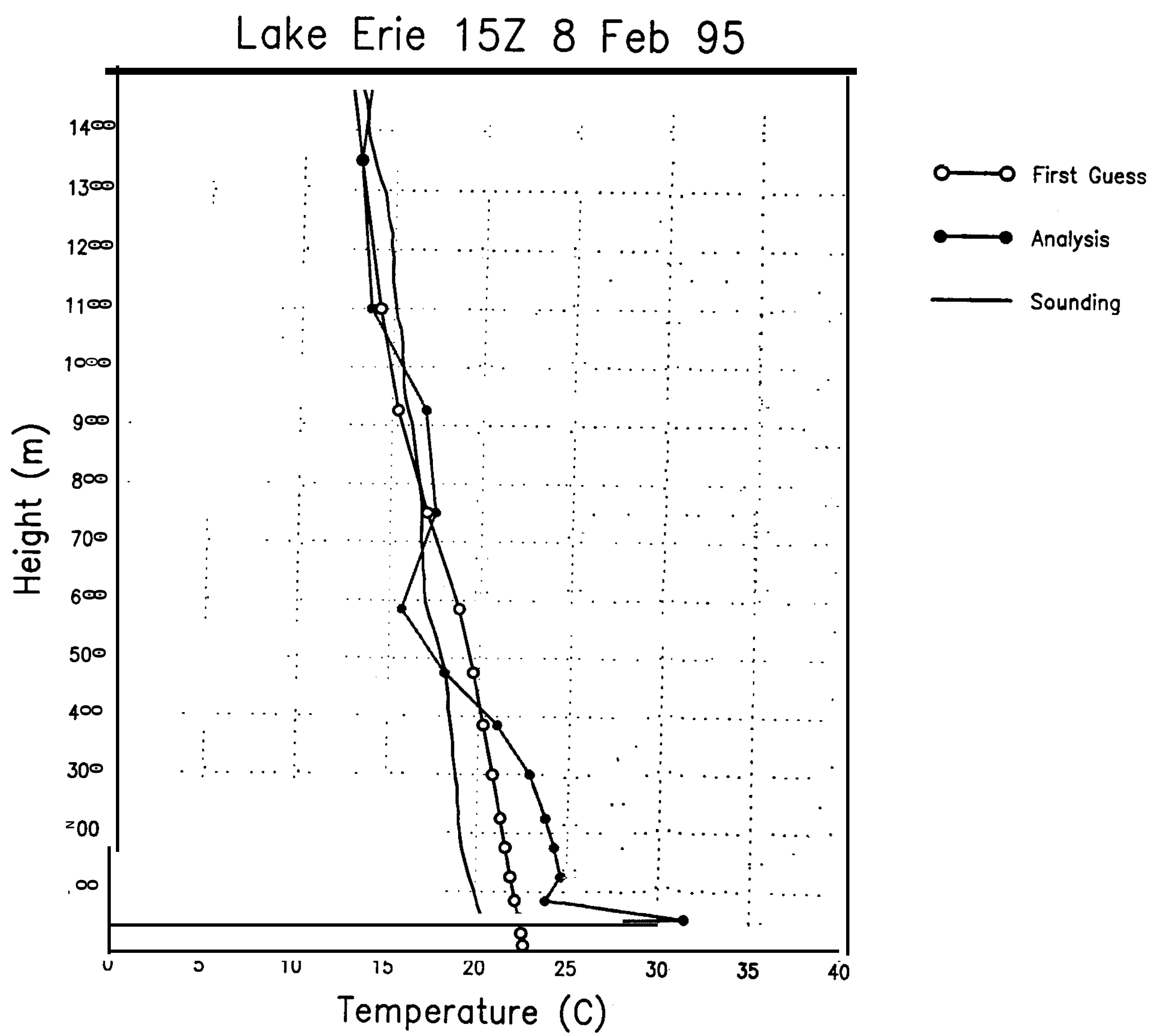
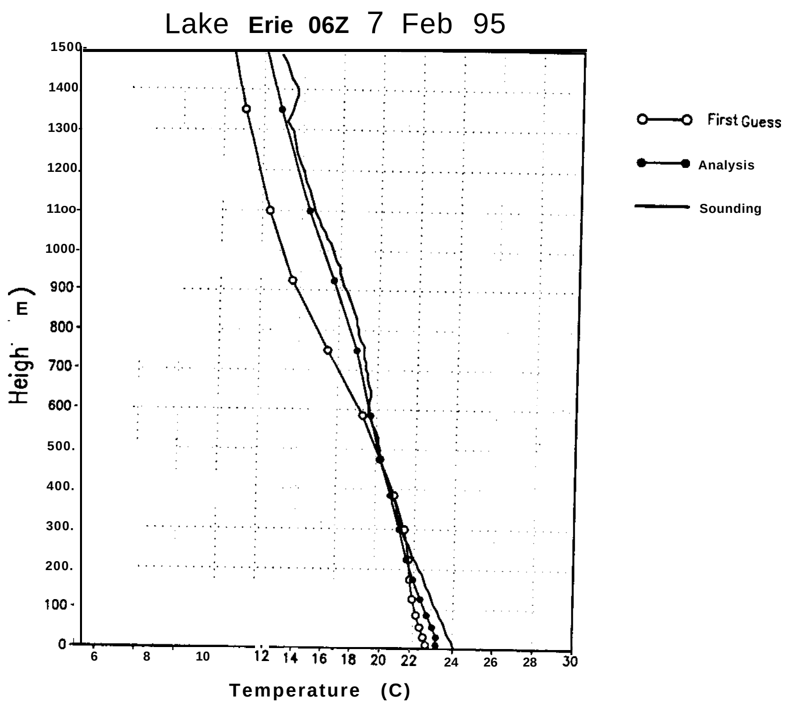


Figure 2: Temperature



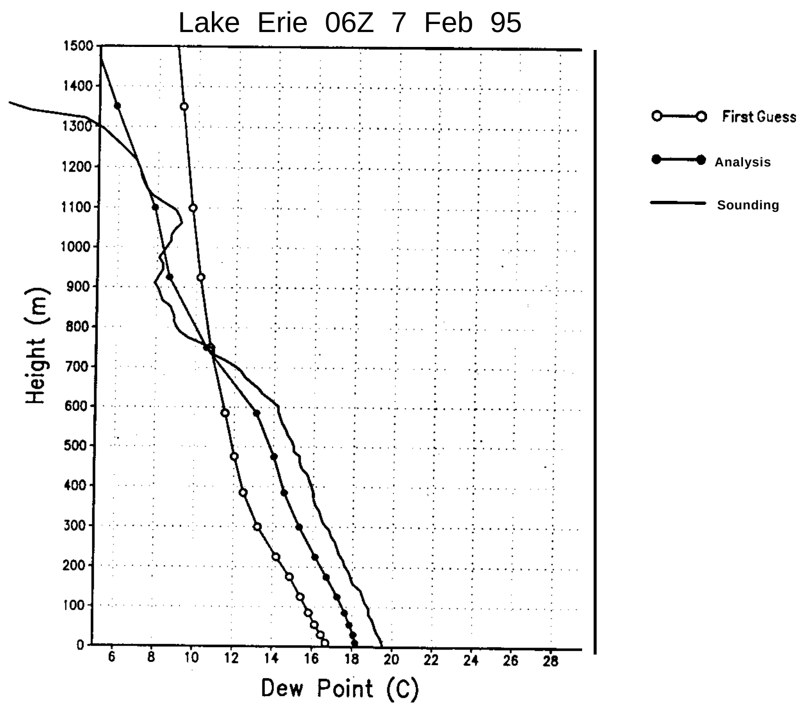


Figure 3: Temperature and Moisture Profiles for Single Sounding Case

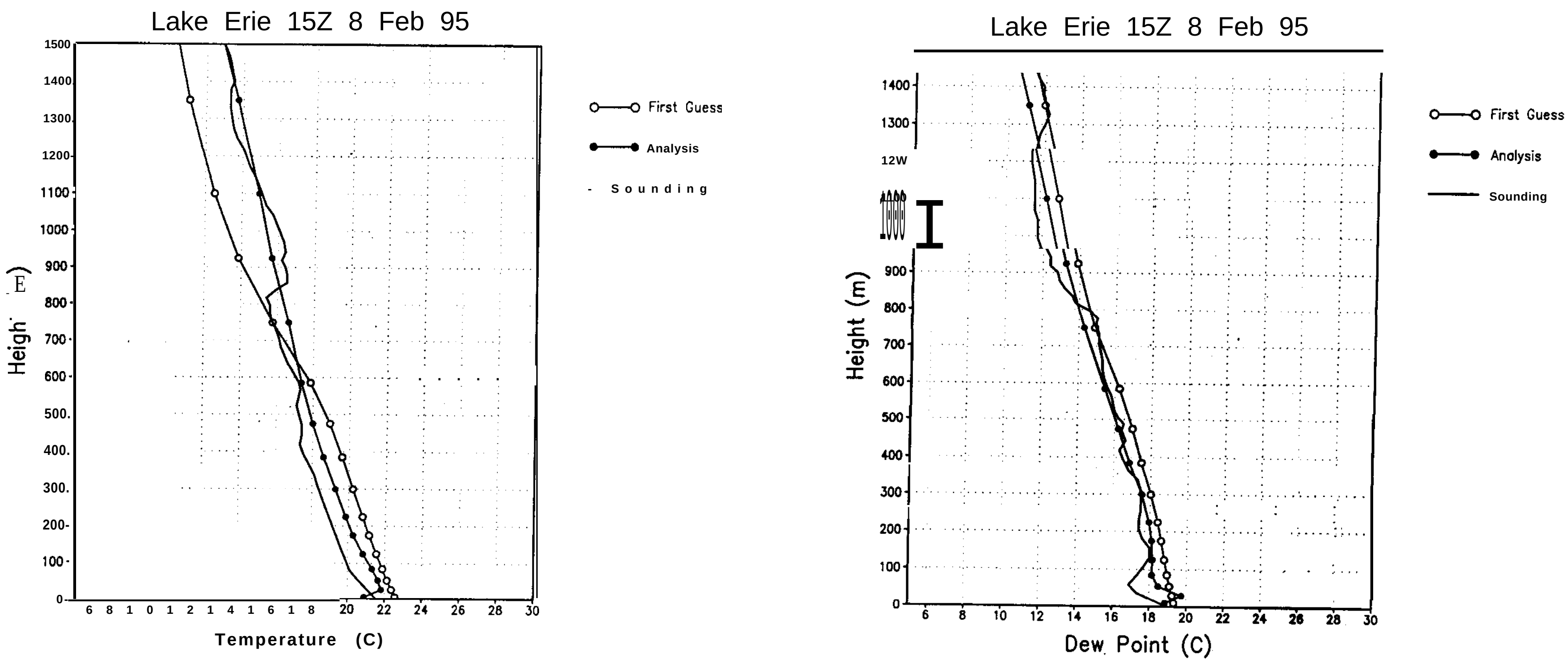


Figure 4: Temperature and Moisture Profiles from USS Lake Erie

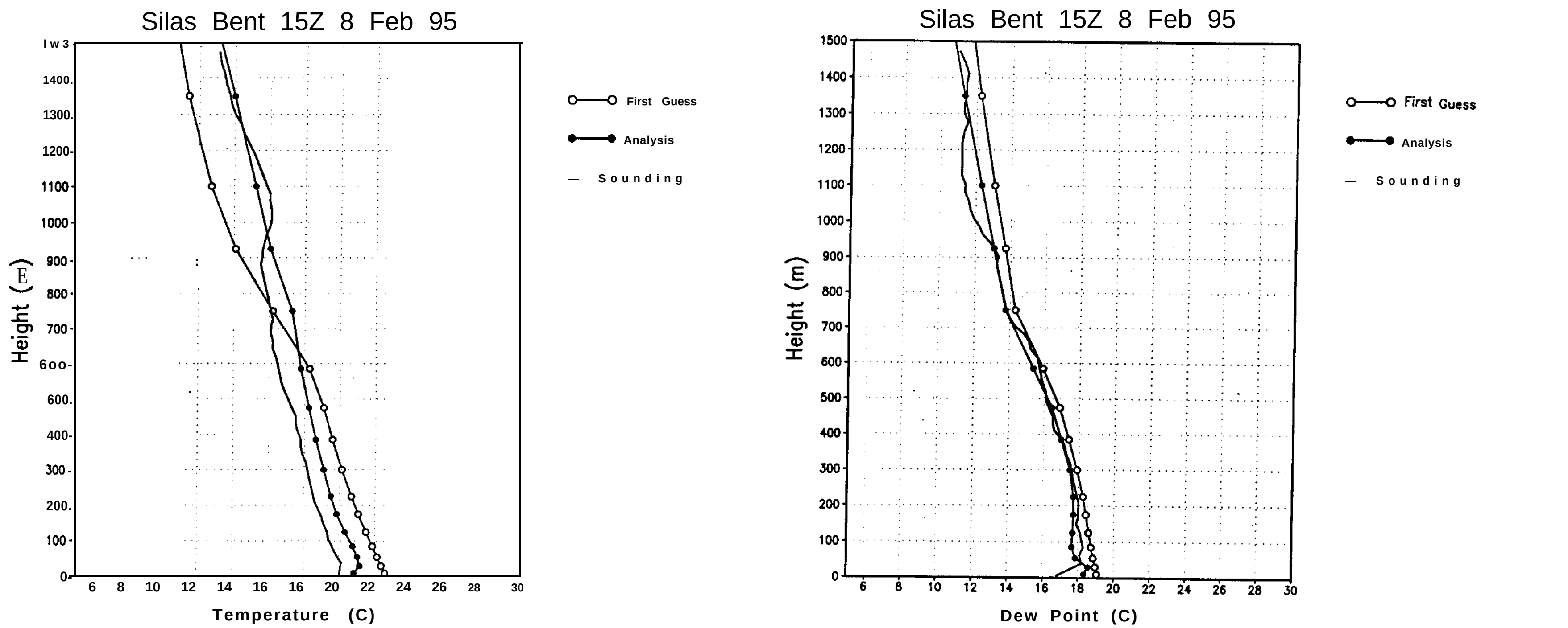


Figure 5: Temperature and Moisture Profiles from USNS Silas Bent

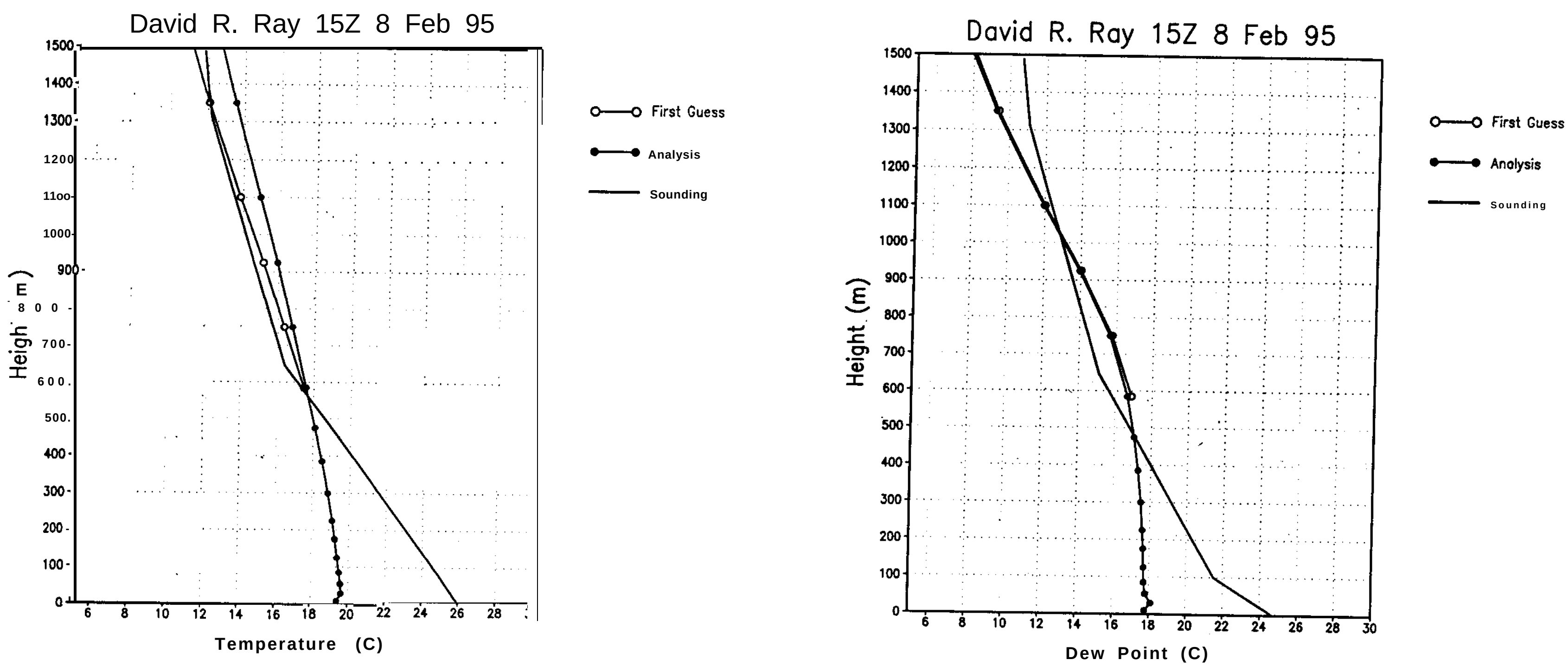


Figure 6: Temperature and Moisture Profiles from USS David R Ray